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Review Article

Analysis of Large Bandwidth Patch Antenna using SRR Technique: A Review

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ABSTRACT

The presented paper is a review of the latest research pronounces the conclusion of the study and analysis of the significant features of the metamaterial, the SRR with a single ring and split ring resonators based on the different results of aggregated work. The antenna characteristics have been investigated in terms of the impedance bandwidth, surface current distribution, maximum gain, radiation efficiency, and radiation pattern. The simulation results demonstrate the effect of SRR on the patch antenna and its performance. It is shown that there is return loss improvement and significant resonant frequency modification by employing innovative split ring resonators into the design.

KEYWORDS

Microstrip antenna, Metamaterial, Frequency range, SRR resonator.

1. INTRODUCTION

The wireless communication systems form an important pillar of Information Technology applications. The meaning of the term 'wireless communication' is the transfer of any information from one place to another (over a distance) using electromagnetic or radio waves. The Internet of Things (IoT) which involves the internetworking of physical devices, vehicles, devices, and the other items embedded with electronics, software sensors, actuators, and network connectivity enables these objects to collect and exchange data [1], of which the wireless communication forms an important part of it. The wireless communication systems demand the features like lightweight, low profile, low cost, the ability to easily get combined with design and technology, low power operation, low loss performance, small size, and the simpler methods of fabrication of the related components due to which they can be readily used in our day-to-day life, leading to smart and omnipresent solutions. An antenna is a crucial component or one of the irreplaceable parts of any wireless communication system. It is an electronic component that radiates electromagnetic waves into the different mediums of communication which transfers the signals/data-carrying amount of information by means of electromagnetic radiation. It is a crossing point of the input and output interface of any of the wireless equipment. The superlative requirements of microstrip-based antennas are that they must be budget-friendly, easy to manufacture, and compact in terms of electrical length as per the requirement of new age group wearable devices. The microstrip antenna accomplishes the above requirements after some modifications and hence, it is extensively used in many wireless applications. When talking about the basic construction of a patch antenna it an attractive low-profile radiating device consisting of a conducting patch (also known as 'radiating patch') which radiates electromagnetic energy after excitation this patch is placed on the top of a dielectric material with a metallic ground plane beneath it. There are various shapes which is implemented on patch antenna viz. rectangular, square, triangle, circle, hexagon, etc. The exclusive feature of a patch antenna is its two-dimensional construction. They are used for broadband applications and applications where the operation at multiple resonant frequencies is required. Their important applications include the handset terminals of mobile communication, the next-generation wireless communication where the high speed of networking for multimedia applications is a prime requirement. The other advantageous features of microstrip antennas because of which they are popularly used are, their ease of mass fabrication using printed-circuit technology (photolithography), ease to integrate with other MICs on the same substrate, ability to generate both linear and circular polarization.

The rest of the paper is divided into three different sections section II describe the basic properties of patch antenna along with the concept of metamaterials. In section III we have presented the latest literature accompanied by the help of split-ring resonator (SRR) patch antenna and other metamaterial and its effect on the performance parameter of a patch antenna, finally, a conclusion is drawn in section IV which give us a glimpse of the pros and cons of using SSR as a technique for patch antenna design and also pave the path of future work.

2. Theory of Microstrip Antenna

In order to fabricate a Microstrip patch antenna, microstrip structure plays an important role in the performance parameters of antenna, to find a proper comprehension of the microstrip, different lumped element in the form of patch is implemented in antenna design. A microstrip antenna may have any structure that is able to encompass at least one oscillating electromagnetic field. There are several measures of implementing microstrip resonators. In general, microstrip resonant frequency for antenna designs depends of the substructure as well as super-structure of dielectric material, this is the part where we have a grate scope of designing metamaterials in the microstrip antennas in order to obtain better performance parameters. Increasing the radiation directivity and reducing the size of antennas at fixed sizes of emitters is a crucial task in the designing of antennas. One possible way to solve this task is placing a layer of metamaterial between the substrate and the patch. Transmission attributes of microstrips are portrayed by two parameters, in particular, the effective dielectric constant $\boldsymbol{\varepsilon_{re}}$ and characteristic impedance Zc, which may then be acquired by quasi-static analysis

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{10}{u}\right)^{-ab} \quad (1)$$

where $u = W/h$, and

$$a = 1 + \frac{1}{49}\ln\left(\frac{u^4+\left(\frac{u}{52}\right)^2}{u^4+0.432}\right) + \frac{1}{18.7}\ln\left[1+\left(\frac{u}{18.1}\right)^3\right] \quad (2)$$

$$b = 0.564\left(\frac{\varepsilon_r-0.9}{\varepsilon_r+3}\right)^{0.053} \quad (3)$$

The accuracy for script model is better than 0.2% for $\varepsilon_r \leq 128$ and $0.01 \leq u \leq 100$. The expression for the characteristic impedance is

$$Z_c = \frac{\eta}{2\pi\sqrt{\varepsilon_{re}}}\ln\left[\frac{F}{u}+\sqrt{1+\left(\frac{2}{u}\right)^2}\right] \quad (4)$$

where $u = W/h$, $\eta = 120\boldsymbol{\pi}$ ohms, and

$$F = 6 + (2\pi - 6)\exp\left[-\left(\frac{30.666}{u}\right)^{0.7528}\right] \quad (5)$$

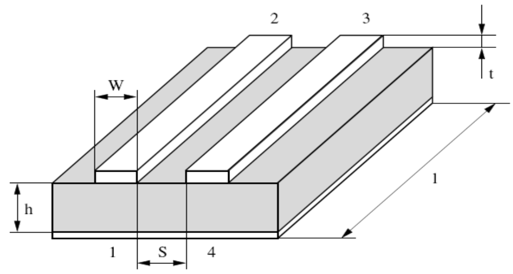

Fig:1 Basic microstrip line

a) Metamaterial

Metamaterials based on spiral resonators are considered, their characteristics are investigated and effective electrophysical parameters of SR-metamaterial are given, the results of comparison of metamaterials based on various modifications of resonators (SRR, SR) and the efficiency of their use as substrates of microstrip antennas are given. Modeling of metamaterial characteristics is considered based on a layer of infinite dimensions. The currently available artificial structures are realized by using planar structures with specific topology in the x–y plane. These two-dimensional structures offer improved permeability in the normal direction of the plane of the metamaterial surface and improved permittivity in the tangent direction of the X-Y axis plane.

$$\dot{\mu}_{eff} = 1 - \frac{f_{mp}^2 - f_0^2}{f^2 - f_0^2 - j\gamma f}, \quad (6)$$

where f is the frequency of applied microwave signal, f_{mp} is the frequency of magnetic plasma, f_0 is the resonant frequency of split-ring structure, γ is the conductivity of material applied.

It's the metamaterial that controls the radiation of electromagnetic waves, especially in the waveguide, and regulates the direction of radiation as well. So far is the far-field radiation being concerned, the edge radiation will be abridged and headfirst radiation can be boosted which is clearly observed in the results of the radiation pattern. Hence, overall improvement in, the directional parameters with progressive antenna gain in waveguide medium can be achieved.

b) Split Ring Resonator

A **split-ring resonator** (**SRR**) is one of the underutilized classes of metamaterial used to generate desired magnetic and electrical properties in millimeter waves for the Terahertz frequency range. The split-ring resonator is a class of metamaterial that holds the properties of composite material in most cases they exhibit a unique response to the applied electromagnetic field depending upon the design of split-ring resonator the response of EM wave is similar to that of the interaction of light with day to day material such as glass with the introduction of periodic splitting in terms of air generate negative propagation of electromagnetic waves especially in microwave region this concept of essays are based on metamaterial is not new but the quantum of its utilization is very low and hence great scope for research by means of lower electrical length and smaller latest constant with respect to the applied wavelength of electromagnetic wave. literature review

In this part, we will discuss the latest research which is going on in the present era, especially in the field of mutual coupling reduction and metamaterials application in microstrip patch antenna designing.

3. LITERATURE REVIEW

[1] S. R. Boroujeni et.al. In this research article, a phased-array antenna is proposed with decoupling the elements which is decoupled by embedding non-radiating coupled resonators between the elements. The antenna is designed with the resonance frequency of the resonators, proper transmission zeros can be created within the operating bandwidth and wide bandwidth of isolation can be formed. The suggested technique is convenient for scalable phased-array structures with no area overhead or extra loss and complexity in the feed network. A mutual coupling reduction of more than 10 dB is achieved over the entire operating bandwidth.

[2] M. J. Veljovic et.al. In this research, An L-band patch-antenna system is analyzed for CubeSat applications. The structure of the antenna is designed in such a way that high-permittivity dielectric loading reduces the size of individual antennas with two circularly polarized patch antennas for the downlink and uplink frequencies of 1.53 and 1.63 GHz, respectively. The investigation shows that the L-band patch antennas and arrays possess a small size and a large beamwidth of 90° and patches provide two 45° x 90° duplex beams for increased capacity, and the uplink array is analyzed. The designed patch arrays can be adopted for other CubeSat scenarios, where only two 3U solar-panel wings are available. In this context, a suitable dual-band antenna element would reduce the total number of required antennas to four.

[3] B. Mao et.al. In this review, a wideband unidirectional antenna constitutes a shorted bowtie patch antenna and a printed dipole. With the addition of a pair of parasitic patches above the printed dipole, the antenna's bandwidth is amplified. The results of the measurement show an impedance bandwidth of 84.7% for SWR ≤ 2 from 2.09 to 5.16 GHz and a stable radiation pattern with low cross-polarization, low back radiation with an antenna gain of 9±2.2dBi is accomplished over the operating frequencies.

[4] M. Jahangiri et.al. In this article, artificial structures of Metamaterial antennas constituent electromagnetic materials by manipulating their structures. Metamaterial antennas are some kinds of antennas that use metamaterials to increase the performance of small antenna systems and also ameliorate the radiation power of the antenna. The conclusion of this article is metamaterial structure as a coating on an antenna to improve the performance of a microstrip patch antenna with coaxial feeding and also antenna gain increased exceptionally and the half-power beamwidth was decreased about 10 degrees. The article also concludes that by evaluating antenna radiation patterns the metamaterial can be used to improve radiation, direction, and lens for electromagnetic radiation.

[5] H. Li et.al. In this study, An ultra-wideband(UWB) multiple-input and multiple-output(MIMO) antenna is explored and analyzed to improve mutual coupling and split-ring resonator(SRR) for automotive communications. The formation of the antenna comprises of the compact size of 54×33mm ^{2} with two parallel monopoles. The outcome of this study shows the antenna exhibits dual band-notched characteristics at 5G band (3.3-3.6GHz and 4.8-5GHz) and also radiation and S-parameters show that the antenna has achieved better results at the entire UWB band suitable for automotive communication

[6] Z. Zaalouni et.al. The objective behind designing a Microstrip Bowtie Patch Antenna with Metamaterial is to resonate at 2.4GHz for radio frequency identification also includes a coherent triangular split ring resonator (TSRR) to the design. The analysis shows that the triangular split ring resonator had been effected the several parameters of the microstrip patch antenna. The result shows by rotating the unit cells from 45° and 90° and 120°, the antenna gain increases to 6.23dbi. In addition, the directional radiation property of a patch antenna maintains. This makes the prefer design useful for RFID applications.

[7] H. E. A. Mahyoub et.al. This paper illustrates and characterizes the characteristics of the metamaterial of the SRR-split-ring resonator, the SRR with a single ring, and SR resonators results obtained are based on these characteristics. A microstrip antenna on a substrate of SR-metamaterial is taken into consideration. The computation of the antenna with SR-metamaterial helps to reduce the resonant frequency of the antenna at the same geometric dimensions of a radiator at almost unchanged antenna gain. The results show the use of antennas that consist of a simulated substrate based on a combination of metamaterial and Ferro A6M material allows minimizing the size of the antenna by almost 60% in comparison with a standard antenna on increasing the operating frequency band.

[8] D. Pattar et.al. In this research paper, the Metamaterial is used to minimize the size of the patch antenna operating in X-band. Many structure are available for the metamaterial but the Split Ring Resonator is the finest method for implementation and fabrication and is also complemented by ground plane structure. Additionally, the substrate permittivity can be altered in order to reduce the frequency range by 34% as compare to normal patch antenna. The observing the result we came to the conclusion that by using ground plane structure which is made from subtracting three Split Ring Resonator Structure from normal ground plane exactly below the patch. This ground plane circuitry can alter the substrate permittivity, to become negative in a certain frequency range. It can be applicable where a miniaturization patch is more important than the gain of the antenna

[9] N. Ulfah et.al. In this article, the antenna is designed in such a way that it should be lightweight, easy to fabricate, and relatively low cost. In order to achieve the following parameters, a Microstrip antenna with Split Ring Resonator (SRR) metamaterial is proposed. On analyzing the simulation results, it can culminate that the gain of the proposed antenna is more than 2 dBi with a directional radiation pattern and horizontal polarization and it also enhances antenna bandwidth with SRR metamaterial by 400% in comparison with conventional microstrip antenna

[10] M. S. Soliman et.al In the research article, an antenna is fabricated and designed in such a way that its modified structure eliminates WiMAX of 3.3–3.7 GHz and WLAN of 5.15– 5.825 GHz. To accomplish the operation in the above-proposed band a compact in size but an ultra-wideband (UWB) patch antenna has been operating in a frequency range of 3.02 GHz to 13.84 GHz in which they achieve a dual-band of operation with the help of notched characteristics. Here a mirror image of the L-shape has been etched at the feed line of the metallic patch to confirm the better performance of a dual-band notch, for bypassing the

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WiMAX frequency range. In order to bypass the WLAN frequency range an additional, split ring resonator (SRR) slot is outlined at the lower end of the metallic patch. After analyzing the results they achieve improved impedance bandwidth even more than 10 % of radiating frequency along with other antenna performance parameters which include high antenna gain, surface current distribution, radiation pattern, and radiation efficiency, which shows appropriate performances in terms of patch antenna design.

4. CONCLUSION AND FUTURE WORK

The proposed works of this typescript are organized in different section, first, we have given the introduction about the Microstrip antenna with metamaterial including SRR. In section, second, we have discussed the theory about Microstrip, Metamaterial, and Split ring resonator with the given data available about all this. In the next part, we have aggregated the latest research in the field of SRR technology applied for patch antenna design.

After concluding the various latest research, we can say that by using metamaterial with SRR, the impedance bandwidth of the antenna enhanced in comparison with conventional microstrip antenna. The other parameter such as maximum gain, radiation efficiency, radiation pattern, etc. performance improves significantly. The use of metamaterial with SRR makes the antenna cost-efficient and compact in size. Hence the use of SRR opens the door of further research in metamaterial-based patch antennas.

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